

Coupled 3-Dimensional Modelling

Roger Proctor
Proudman Oceanographic Laboratory, Bidston Observatory
Wirral CH43 7RA, UK

phone (+44) 151 653 8633; fax (+44) 151 653 6269; email rp@pol.ac.uk

Person (s) Visited

(a) Ruth Preller, Cheryl Ann Blain, Tim Keen, John Kindle, Paul Martin
Address NRL Stennis Space Center, MS 39529-5004

phone (228) 688-5444; email preller@seahorse.nrlssc.navy.mil

(b) Rich Signell

Address USGS, Woods Hole Oceanographic Institution, Ma 02543-1598
phone (508) 457-2229; fax (508) 457-2310; email rsignell@usgs.gov

Award Number: N00014-00-1-4045

<http://www.pol.ac.uk>

LONG-TERM GOALS

To understand the dynamics of physical oceanographic processes on continental shelves and slopes and explain their impact on nutrient cycling, biological production and pollutant dispersion with a view to developing models for operational forecasting of the health of coastal seas.

OBJECTIVES

- 1) To foster collaborative links between US (NRL) and UK (POL) operational modellers.
- 2) To disseminate European experience of developing coupled hydrodynamic model frameworks.
- 3) To 'get up to speed' with US operational & pre-operational modelling and identify areas of potential collaboration to enhance both (US, UK) groups efforts.
- 4) Attend USGS Workshop 'Community Sediment Transport Modeling Workshop' 22-23 June 2000 and present experience with EU Project COHERENS.

APPROACH

- (a) NRL SSC are involved in the development and establishment of pre-operational and operational marine models for the US Navy. POL in the UK are contracted by the UK Met Office to provide similar models for insertion into the Met Office's operational suite, providing information to civil and naval authorities. The scope for rationalisation and sharing of expertise was the main thrust of the visit to NRL SSC.
 - (i) POL has been involved in providing operational guidance to tide and storm surge prediction for over 25 years, through the running of a 2-dimensional tide-surge model for the north west European Shelf. This model is relocatable and has been used in many regions around the globe and at resolutions ranging from 1 degree (near global) down to 100m in estuaries.

Key researchers at POL involved in this work are Roger Flather and Roger Proctor. Discussions on the differences between the NRL SSC relocatable tide-surge model (key NRL SSC scientist Ruth Preller) and the POL model focussed on the GUI of the NRL SSC model and the models' performance in comparable locations. The two groups have been involved in joint work in the Mediterranean (focus Adriatic Sea), with emphasis on surge prediction, resulting in a recent publication (Wakelin *et al.*, 2000).

- (ii) Both POL and NRL SSC have produced 3-dimensional baroclinic models which are running operationally. NRL SSC have NCOM written by Paul Martin, POL have POL3DB written by Ian James, Roger Proctor and Jason Holt. Discussions between Martin & Proctor centred on the ways the models behave in the presence of steep topography and the numerical methods required to resolve the associated problems. The open boundary conditions of the models were also discussed. POL3DB is written in a form suitable for parallel computers, which allows its use across a wide range of computing platforms from single workstations to large machines like the CRAY T3E (POL use the Manchester 800 processor machine and will shortly be transferring the model to the Met Office 700 processor machine) and this is the next development in the NRL SSC modelling.
- (iii) An important component in running 3-dimensional models is an ability to visualise the results because of the large volumes of data produced. POL have been investigating a number of packages to perform this visualisation (e.g. PVWAVE (IDL), AVS). NRL SSC are currently evaluating a sophisticated package produced in Canada by Baird called X-Vision. This package was demonstrated to me by Shelley Reidlinger who works for Ruth Preller. The package, when run on a powerful workstation, allows fast display of any 2-dimensional section from a 3-dimensional dataset and the production of animated sequences of this section. It also allows the overlaying of properties, such as isosurfaces of salinity (say) and fixed depth currents. This package provides the flexibility POL requires but is probably too expensive for us, so seeing its functionality has provided me with ideas for modifications to our in-house software.
- (iv) POL (particularity Alan Davies, Jiuxing Xing & Roger Proctor) is interested in introducing unstructured grids into its models, allowing the efficient inclusion of the appropriate resolution where required (e.g. near coasts and in regions of rapidly changing bathymetry). Cheryl Ann Blain at NRL SSC has experience of using two of the major unstructured models available to the marine community, the QUODDY model produced by Dan Lynch at Dartmouth College, and ADCIRC produced by Rick Luetich at University of North Carolina. Both these models use finite elements in the horizontal but approach the time integration in different ways. I was interested in hearing her experiences, and in particular about her recent work with QUODDY in the Persian Gulf, an area I have modelled in the past.
- (v) The POL3DB model forms the basis of a coastal ocean modelling system being developed at POL called POLCOMS (POL Coastal Ocean Modelling System). The parallel implementation of this code has meant that we have been able to couple the 3-dimensional hydrodynamics with sediment transport and ecosystem modules. In particular we have coupled ERSEM (European Seas Regional Ecosystem Model) to POL3DB allowing biological-physical interaction at the physical timestep. ERSEM provides a near-complete description of the marine ecosystem including nutrient cycling (nitrate, silicate, phosphate) and plankton production (phytoplankton (flagellates, diatoms) and zooplankton, partitioned into size classes) with pelagic and benthic interaction including sediment erosion, deposition and transport. POL (Roger Proctor, Jason Holt) has applied this model to annual simulations on the north west European shelf. NRL SSC (John Kindle) are involved in a

NOPP program to set up an ecosystem model for the North Atlantic with the Fasham model embedded. POL (Proctor, Holt) are also involved in a NERC Thematic Programme called Marine Productivity in which they will compare the performance of the Fasham model with the ERSEM model within the Irish Sea. This was of interest to Kindle in view of the NOPP program. We agreed to stay in contact over relevant developments. Additionally, Tim Keen at NRL SSC is involved in modelling sediment transport, particularly the combination of sediments into optical models, so I had discussions with him on the different algorithms used. Keen was also planning to attend the USGS Community Transport Modeling Workshop (see (b)) so we had preliminary discussions on what the workshop may produce.

- (b) The USGS organised Community Sediment Transport Modeling Workshop was held 22-23 June 2000 at Woods Hole Oceanographic Institution. This was to address the question ‘does the US require a Community Model?’ (a report of the meeting is available at http://oracle.er.usgs.gov/sed_workshop). The meeting was hosted by Rich Signell, Courtney Harris and Chris Sherwood. POL (Roger Proctor, Eric Jones, Andy Tabor) have been involved in a European Union part-funded project called COHERENS (Coupled Hydrodynamic Ecosystem for Regional Seas). This is a follow-on from an earlier EU project called PROFILE (Processes in Regions of Freshwater Influence) which aimed to observe and model 3-dimensional hydrodynamics, sediment transport and microbiology in coastal seas affected by river inflows. COHERENS (coordinated by Patrick Luyten in MUMM, Belgium) took the 3-dimensional model developed in PROFILE and prepared it for use as a community model by modularising the code, providing full documentation, data and graphical interfaces, and giving a range of test cases (>50) and cross-platform installation details. A CD ROM containing all components including the code was released in April 2000 and details can be found on <http://www.mumm.ac.be/coherens>. Roger Proctor and Alex Souza (a POL COHERENS user) attended the workshop to provide input on our experience with this community model, particularly on the components required (and the effort involved) in setting up such a system. Significant interest was shown by workshop participants in the COHERENS model and 15 CD’s were distributed. The list of registered users worldwide now exceeds 100.

TRAVEL COMPLETED

Table 1. Summary of visits conducted under this VSP.

Person Visited	Position	Institution / Conference	Location	Purpose	Dates (mm/dd/yy format)
Ruth Preller	Section Head	NRL	Stennis SC	Modelling	06/19-20/00
Shelley Riedlinger	Scientist	NRL	Stennis SC	Visualisation	06/19-20/00
Tim Keen	Scientist	NRL	Stennis SC	Sediment transport	06/19-20/00
Paul Martin	Scientist	NRL	Stennis SC	3-D Modelling	06/19-20/00
John Kindle	Scientist	NRL	Stennis SC	Ecosystems	06/20/00
Cheryl Ann Blain	Scientist	NRL	Stennis SC	FE Modelling	06/20/00
Rich Signell	Scientist	USGS	Woods Hole	Workshop	06/22-23/00

RESULTS

Visit to NRL SSC: (a) Relocatable models, shared expertise on problems and solutions to relocation, possibilities for future intercomparisons; (b) mutual exchange of numerical methods for countering the effect of steep bathymetry in sigma-coordinate models, agreed continued contact regarding parallel model developments; (c) insight into capability of a high powered visualisation package, enabling me to draw up an action list for visualisation development in POL; (d) a better appreciation and understanding of the ability of the finite element method to model 3-dimensional hydrodynamics, obtained some useful knowledge on the ease of use of the two main f.e. models, and some appreciation of their limitations, this information will be useful in future POL decisions on opting for a finite element method; (e) shared knowledge on ecosystem models for the north Atlantic will benefit both groups, future exchange of information agreed.

Visit to USGS Workshop: Workshop (as meeting minutes affirm) agreed the need for a community sediment transport model, provided a number of criteria were met. The COHERENS framework was the most advanced model framework presented and the COHERENS framework satisfied many of the criteria for a US community model. USGS will assess existing model frameworks (including COHERENS) as a suitable starting point for the US Community Model. As in Europe it was identified that observations and models needed further development and effort put into algorithms for cohesive & non-cohesive sediments, particularly erosion & deposition functions for multi-sediment types. POL work on sediment dynamics is running parallel to the US developments and there are clear benefits of continuing contact.

IMPACT/APPLICATIONS

- (a) Closer collaboration on the development of pre-operational and operational model applications stands to benefit both the US and UK groups. Exchange of knowledge and experience on numerical methods, parallel computing application and ecosystem modelling will advance science nationally and internationally.
- (b) Sharing expertise on community model requirements, and on sediment transport in particular will enhance the capabilities of both scientific communities. There exists the potential to integrate expertise to the greater good. US and UK (and EU) groups are working along similar lines, with the US concentrating at present on community sediment transport whereas the UK (POL) is expanding the capability to a community ecosystem model (POLCOMS).

TRANSITIONS

- (a) Improved operational oceanographic forecasts will be of benefit to both naval and civilian communities worldwide. Rapidly relocatable models which produce accurate forecasts will enhance the success of military operations and provide detailed information for both military and civilian authorities in the event of marine accidents involving, for example, oil and chemical spills, and search and rescue.
- (b) Well organised, structured, proven and maintained community models will be of great benefit to the academic and non-academic communities. The availability of such model systems (e.g. downloaded from a web site or provided on a CDROM) will provide experts with the tools to advance model development in their speciality without the need to acquire in-depth knowledge of all aspects of marine modelling. By providing insight into the limits of predictability of the

community model, non-specialists will be able to assess their own contributions or their application results with confidence.

RELATED PROJECTS

POLCOMS – POL Coastal Ocean Modelling System, a framework for integrating hydrodynamic motion with sediments, pollutants and ecosystem response. (<http://www.pol.ac.uk>)

POL Sediment Dynamics programme – focussing on mobile sediment patch off the Dee Estuary in the Irish Sea, and planning to integrate real time measurements with POLCOMS model framework. (<http://www.pol.ac.uk>)

EU Projects NOMADS (North Sea Model Advection & Dispersion Study) and PROVESS (Processes of vertical exchange in shelf seas) both using COHERENS model framework in 3-dimensional simulations. (<http://www.pol.ac.uk>; <http://www.mumm.ac.be/coherens>)

PUBLICATIONS

- Allen, J.I., J. Blackford, M.I. Ashworth, R. Proctor, and J.T. Holt (in press). A highly spatially resolved ecosystem model for the Northwest European continental shelf. *Sarsia*.
- Ashworth M, R. Proctor, J.C. Blackford, and J.I. Allen (in press). Coupled marine ecosystem modelling on HPC systems. *Proceedings of Parallel CFD'99*, 23rd-26th May 1999, Williamsburg, Virginia, USA. Elsevier Science Publication.
- Lockey, P., R. Proctor and I.D. James (1998). "Parallel implementation of a 3D baroclinic hydrodynamic model of the southern North Sea." *Physics and Chemistry of the Earth*, **23**(5-6): 511-515.
- Lockey, P., R. Proctor and I.D. James (1998). "Characterization of I/O requirements in a massively parallel shelf sea model." *International Journal of High Performance Computing Applications*, **12**(3): 320-332.
- Luyten, P., J.E. Jones, R. Proctor, A. Tabor, P. Tett and K. Wild-Allen (1999). "Dissemination of a coupled hydrodynamical-ecological model for regional and shelf seas (COHERENS) and validation with North Sea data sets." p.98 in, *2nd International EUROGOOS Conference: Extending the Limits of Predictability*, Rome, 10-13 March 1999, I.M.C.
- Proctor, R., P. Lockey and I.D. James (1999). "Development of portable shelf sea models for massively parallel machines". 359-364 in, *High-performance computing*. R. J. Allan, Ed. New York: Kluwer Academic/Plenum Publ.
- Proctor, R., J.T.Holt, J. Harris, A.D. Tappin and D. Boorman, (in press). Modelling the Humber Estuary catchment and coastal zone. *Proceedings of 6th International Conference on Estuarine and Coastal modelling*, 3-5 November 1999, New Orleans. ASCE publication.
- Tartinville, B., E. Deleersnijder, P. Lazure, R. Proctor, K.G. Ruddick and R.E. Uittenbogaard (1998). "A coastal ocean model intercomparison study for a three-dimensional idealised test case." *Applied Mathematical Modelling*, **22**(3): 165-182.
- Wakelin S.L., R. Proctor, R. Preller and P. Posey (2000). The impact of meteorological data variability on modelling storm surges in the Adriatic Sea. *Proceedings of the 1999 European Geophysical Society Plinius Conference on Mediterranean Storms*, 497-508.